NUMERICAL MODELING OF ACOUSTIC PROPAGATION IN A VARIABLE SHALLOW WATER WAVEGUIDE

Daniel Rouseff
Applied Physics Laboratory
College of Ocean and Fishery Sciences
University of Washington
1013 NE 40th Street
Seattle, WA 98105
email: rouseff@apl.washington.edu
Telephone: (206) 685-3078 Fax: (206) 543-6785
Award: N00014-96-1-0152

Shallow-water acoustics

LONG-TERM GOALS

The long term scientific goal is to better understand the effects of shallow water variability on acoustic propagation at moderate frequencies. Potential sources of water column variability include random background internal waves as well as quasi-deterministic, event-like soliton packets.

OBJECTIVES

The objectives of the present work are to develop simulation routines and data analysis tools useful in achieving the long-term scientific goal.

APPROACH

Acoustic propagation is simulated using both the parabolic equation and normal modes. Environmental measurements and models are incorporated in the simulations.

WORK COMPLETED

Under previous support, a suite of computer routines were developed to study the combined effects on acoustic propagation of roughness in the random sea surface and the water-sediment interface, as well as water column variability [D. Rouseff and T. E. Ewart, 1995]. Under current funding, these numerical models continued to be improved and found greater application. Emphasis was on shallow water simulations at frequencies between 200 Hz and 2 kHz. Siderius and Rouseff studied the effects of bottom roughness on acoustic mode coupling and the implications of this coupling for solving acoustic inverse problems. Specific results showed how as the degree of roughness is increased an inversion can be improved by adding additional sources. These results were an integral part of a graduate student Ph.D. dissertation [M. Siderius, 1996] and were presented at an Acoustical Society Meeting [D. Rouseff and M. Siderius, 1996]. A mode coupling analysis was developed to study the concept of an acoustic guide source to compensate for multipathing [M. Siderius, D. R. Jackson, D. Rouseff, and R. P. Porter, 1997]. The simulation tools were also applied to the study of "time-reversed," or "phase conjugate," arrays. A unique feature of the simulations was that the sea surface was modeled "as

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seen" by the acoustics; that is, the temporal evolution of the sea surface was included with the height at a given range selected based on the phase speed of the acoustic wave. This allowed the combined effects of a rough sea surface, a rough bottom, and finite processing time to be studied [T. E. Ewart, D. Rouseff and D. R. Jackson, 1996].

Later in FY97, the emphasis of the work shifted towards modeling and data analysis of the 1995 Shallow Water Acoustics Random Medium (SWARM 95) experiment [PI: M. Orr, NRL; Apel et al., 1997]. The summer of 1997 was spent as a Visiting Scientist at NRL-DC.

RESULTS

Using CTD casts and bathymetric measurements taken during SWARM, acoustic propagation was simulated. At short ranges, there is repeated interaction with both the sea surface and the bottom. At more distant ranges, energy largely hugs the bottom with minimal interaction with the sea surface.

A modal analysis was initiated of SWARM data taken along the 32 element NRL array located 42 km downrange. Both the 224 Hz and 400 Hz data were considered for the same time windows. Because the 224 Hz source was located near the bottom, mode one was only weakly excited. The 224 Hz data showed a strong mode one response, possibly evidence of mode coupling. Three separate versions of mode filtering were implemented: a quadrature scheme that approximates the modal orthogonality condition, a least-squares solution, and a filter that infers the mode one structure directly from early arriving part of the acoustic field. For the time windows considered, the results from the three methods were consistent. Modal decorrelation times of between one and two minutes were observed. This is generally consistent with what was observed along the Woods Hole array located closer to the sources [Headrick, 1997].

IMPACT/APPLICATIONS

Random variability in the water column affects the temporal and spatial correlation scales of the acoustic field. A capability to model the effects of randomness is essential for data analysis and planning future experiments.

TRANSITIONS

An improved understanding of the temporal and spatial acoustic correlation scales may aid in predicting system performance in shallow water.

RELATED PROJECTS

Investigators at other institutions including NRL, WHOI and the Naval Postgraduate School are involved in SWARM analysis.

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